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SPECIALIZED MINE DETECTOR DOG

Interim Report
Contract No. DAADO5-71-C-0195

by
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13. ABSTRACT

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FOREWORD

The following report summarizes work done under Contract No. DAAD05-71-C-0195 for the Land Warfare Laboratory, Aberdeen Proving Ground, Maryland. The purpose of the work was to test the feasibility of using dogs to detect antipersonnel mines (M14 type) which had been buried for long periods of time. Two of the dogs were to be delivered to Aberdeen Proving Ground following field tests of the system. The work was conducted during the period from December 7, 1970 to June 30, 1971. Mr. John Romba was technical director of the project for LWL.

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INTRODUCTION

The objectives of the present contract were to determine the feasibility of having dogs detect antipersonnel mines of the M14 variety which had been buried for considerable periods of time (up to four months, according to the contract specifications; however, see section on Results). The mines were to be detected by the dogs at depths ranging from surface placement to six inches beneath the surface. The dog was to work off-leash within lanes laid out on the mine field and to signal a detection by sitting within two feet of the mine.

Because such mines would have been buried for these considerable time periods, it would be logical to assume that the dog could make detections of the subsurface mines only by forming appropriate odor discriminations -- extraneous visual cues such as visible earth disturbance, differential settling of the area around the emplacement, etc., should presumably be eroded away over the time periods involved. However, it does not matter what cues the dog might be utilizing; the basic question is a pragmatic one -- can the dog, using whatever evidence is available to it, make the required detections?

CONCLUSIONS

1. The dogs have the capability of detecting mines to a depth of at least 4 1/2 inches, possibly somewhat deeper, when all conditions are optimal.

2. The reliability of detections at depths in excess of an inch or two is low.

3. A reliable, practical buried mine detection system could not be demonstrated. The dogs' scan or search pattern did not permit reliable one-pass inspection and detection of a given lane under the conditions in which the test took place.

4. There are possible ways of optimizing the success of future attempts to develop a reliable system. One suggestion would be to narrow the lane in which the search was to take place so that the degree of side-to-side scan is not great. Another possibility would be to work the dog on-leash and require the dog to canvass an area thoroughly before the handler would permit it to move on to search a new area within the lane.

5. Closer simulation during the training situation of field conditions at the test site might also be advantageous. We also suggest that the dog be permitted, even encouraged, to dig for the mine, thus pinpointing exactly the location of the mine and allowing for more certain verification.

DEVELOPMENT OF THEORY

Dogs have been previously used for detection of buried articles including mines. Many past experiments have demonstrated that dogs can make fine olfactory discriminations of a variety of stimuli and can make appropriate responses to the stimuli in question to signal to a human handler that such a discrimination has been made.

The training methods used for the establishment of the discriminations in the present group of dogs are those of operant conditioning as described by Skinner, Ferster, Breland and Breland, and others. Positive reinforcement (praise and food) was used as the basis for conditioning the discrimination to the presence of the mine.

Aversive stimulation was held to a minimum in order to preclude its undesirable side effects. Motivation for food was kept at a high level so that the dogs were eager to work for the food reinforcements; however, since the dogs were still young and growing, severe conditions of deprivation were avoided.

METHOD AND PROCEDURES

To implement the achievement of the goal of the project, the Land Warfare Laboratory of Aberdeen Proving Ground furnished Animal Behavior Enterprises with one thousand plastic antipersonnel mines (M14), presumably identical except for the explosive charge, with those buried in a field at APG which would represent the field test site and similar to those which might be encountered in practical problem areas. Instead of carrying a full explosive charge, the mines shipped to ABE were lightly dusted with tetryl on the inside, on the supposition that this dusting would carry enough of the odor of the actual mine charge to render it discriminable by the dog.

ABE purchased in all five dogs -- two Labradors and three Basset Hounds; detail on individual animals is given in the monthly letter reports. The method of training involved preliminary establishment of a discrimination in an indoor working area and transfer of this discrimination, under progressively more difficult and stringent conditions, to outdoor fields in which mines had been buried. One field was set up in time so that mines would have been buried for a period of four months prior to the end of the training period.

The dogs were trained to scan the areas in question by sniffing and, upon the detection of a mine, to signal such a detection by sitting near the mine (within two feet). Basic simple obedience training accompanied their discrimination training so that handling the animals

would be accompanied by a minimum of "fuss." The method was one of positive reinforcement with food (Prime dog food) and praise; punishment was kept to a minimum and consisted only of disapproval, withholding of reinforcements, delays to next trial, and the like.

Training Procedures:

1. Dogs were given preliminary obedience/exercise sessions prior to the beginning of actual discrimination training. Responses were conditioned to commands such as HERE, HEEL (on- and off-leash), MOVE OUT (to scan an area), STAY, etc. Training to the command SIT was reserved for discrimination sessions at first, although later on, this command was generalized so that the dog could be told to sit, for example, by the trainer's side at the start of a lane, and so on. During these sessions the dogs were encouraged to run around and exercise, at first in a 100 feet x 20 feet pen, later in the open.

2. A discrimination was established to the effect that the dog would sit on detection of a mine. At first the S+ (positive discrimination stimulus) was a bare mine laid on the floor of the training room; the mine was moved around to various locations in the training room. At first the command SIT was given verbally and, if needed, gentle physical pressure was applied to the dog's hind quarters.

These two preliminary procedures were very rapidly dropped; within two or three sessions the dog was required to sit without command or help.

Reinforcement in the form of praise, petting, and two or three pieces of Prime was given as (or just after) the dog sat next to the mine. A bridging stimulus, or secondary reinforcement, in the form of a clicker, was given just prior to food reinforcement, this stimulus having previously been conditioned to the administration of the food reinforcement during the obedience/exercise sessions.

At first only scanning with the nose or, very early, visual scanning for exposed mines, was permitted. Later on digging for a buried mine was deemed to be acceptable by the sponsors, although only one dog (Pearl) did this to any appreciable degree. (One other dog (Sally) had begun this digging behavior, but it was extinguished prior to the time when such behavior was considered acceptable.)

3. After the dogs began to make proper responses to the mine alone, the mine was placed on top of a bucket of washed sand. Soon after the dogs began to respond to this S+, an S- (negative stimulus) was introduced in the form of a bucket filled only with sand, and a discrimination was required. Positions of the "hot" and "cold" buckets, S+ and S-, were changed according to a random pattern in order to prevent formation of position habits.

4. As soon as the above discriminations seemed adequately formed (75 percent accuracy) to the exposed mine, the mine was covered at successively greater depths (1/4, 1/2, 3/4, 1, 2, 3, 4, and 5 inches). The number of buckets were also increased gradually, until up to six were being used in a session, five S-'s and one S+. Data collected consisted of numbers of correct, false and incomplete trials in a session.

5. Gradually, as accuracy of the discrimination increased the SIT time was increased. During this time a second handler would probe for the mine to verify the detection. The first handler would then sound the bridging signal to recall the dog and administer the primary reinforcement.

6. Coincident with discrimination establishment, the dogs were also started on lane holding, or remaining within a lane. These were independent sessions at first, in which the dog was required to move from one point to another within six foot wide lanes marked off with white tape one inch wide. As the dog learned to stay within the lane, detection work was begun with mines placed in buckets in the lanes.

7. Outdoor mine fields were set up and marked off in lanes six feet wide x 24 feet long. At first five empty buckets were buried about two inches below the surface into which "hot" and "cold" buckets could be placed and rotated within any of the five locations. Outdoor fields were also established in which the mines were buried at varying depths in the natural earth, i.e., without buckets. Fifty-five lanes in all were constructed for training.

The width of the lanes was later reduced to three feet to correspond more closely to conditions to be met later at the test site at Aberdeen Proving Ground and also to improve the fineness of "grain" of the scan, i.e., to encourage the dog to do a more thorough scanning of a given area.

The majority of the lanes were 40 feet long; mines were randomly placed throughout each lane, from three to nine mines per lane. Mines were also buried without the string carrying cord. Mines were buried with and without safety clips; those buried with the clips were buried clip down. A total of 35 lanes, approximately three feet wide by (usually) forty feet long were available by the end of May.

8. Dogs were routinely worked on outdoor lanes with mines at varied depths, as described above, through 18 June. In May the dogs were introduced to the four-month-old lane which was 90 feet long (this abrupt change in length, incidentally, seemed to disturb the dogs somewhat and they tended to scan only about the first 40 feet).

9. On 19 June the dogs were transported to Aberdeen Proving Ground for field tests.

Procedural Precautions:

If positive results are achieved in a study of this sort, there is still no absolute guarantee that the dogs are using olfactory cues to make their detections. Nevertheless, there are in the training and test situations many extraneous variables which can be controlled by proper procedural precautions. In training, we attempted to guard against the following extraneous cues (those which could not or would not be operative in a test or field situation) by the means described below:

1. Position or place cues. This is a very common source of extraneous cuing but one which is relatively easy to control. From the very earliest discrimination trials, positions of the S+ were varied, both indoors and outdoors, according to a random placement system.

2. Human cuing.

a. Inadvertent visual cuing was controlled in training sessions by strict instruction of personnel to avoid oral signals, body or hand movements which might guide the dog to the proper location. In many instances, particularly early in discrimination training, one technician would place the "hot" buckets, and their locations would be unknown to the technician who was giving the reinforcement. Only on signal or probe by the first technician would the dog be notified that he had made a correct detection.

b. Human odors were controlled by washing the mines, handling the mines with clean gloves and tongs, using washed sand, allowing minimal contact with the soil surfaces under which the mines were located, disturbance and spreading of any such odors by raking the soil, etc. "Decoy" objects which might bear human odors, as well as other irrelevant odor-bearing objects, were buried in lanes along with the mines; some empty holes were also left. Of course, this type of control would relate both to human odors and other conditions which would be equally extraneous -- soil disturbance, etc.

3. Cuing from odors left by other dogs was controlled by using fresh buckets (in work at that stage) and later, outdoors, insofar as possible, working with each dog on a lane which had not been worked by another dog that day. Each dog was worked in a different set of lanes each session.

4. An attempt to eliminate the physical-visual cues was made by raking and disturbing and then leveling the soil over the excavated areas. An effort was made to make the appearance the same for sites which contained mines, which contained empty holes, and which contained "decoy" objects as described above. In most cases it was not possible to eliminate completely during the time of the training period the slight soil depression which resulted from an excavation and its later settling; however, settling was uniform for both mined holes and decoy excavations.

RESULTS

Training Period: December 7, 1970 to June 18, 1971.

During this time five dogs in all were put through the above procedures. Three were eliminated at different stages, for various reasons. One (Guss) because of deafness, which was not immediately apparent during early training, was dropped January 1971. The second (Molasses) procured in January 1971, was dropped May 6 because of excessive shyness and failure to adapt to training conditions. The third (Sally) was dropped May 17 because of erratic behavior and an excessive number of health problems. All three eliminated were Basset Hounds. Detail on all individual dogs is available in the monthly letter reports. Two Golden Labrador Retrievers, Son and Pearl, completed all training sessions from the beginning of the contract through their delivery to APG in June except for a few sessions missed by Pearl during her oestrus.

Results are given in detail in monthly reports and summarized in the report for May 1971.

The following results are based on the performance of the Labradors, since the behavior of the Bassets was simply too irregular to allow the formation of any conclusions.

Both dogs experienced difficulty in detecting mines at depths greater than two inches. Soil condition was a major variable, hard-packed earth being the most difficult working condition. Reliability tended to increase with decreasing compaction. Occasionally a dog would detect a mine in hard-packed earth at depths greater than two inches, while missing other mines in the same lane. At depths greater than two inches, all behaviors -- scanning, moving out and detections -- would become less reliable, and eventually the dogs would become reluctant to work at all. See Table 1, Appendix A, for a summary of trial results by depth of mine.

Grass and areas of short stubble also proved to be a handicap to detections, as was thoroughly wetted ground -- muddy ground with occasional puddles.

Heat was another obstacle to reliable performance. At temperatures over 85° the dogs tended to pant heavily and during these panting spells would scan very little and tend to overrun buried mines.

In working the four-month old mine field, both dogs successfully detected three of the buried mines, each detecting at least one which had been missed by the other. Both detected one at four inches; one each at two inches and one at one inch. (The high weeds had been cut over this field; several mines, however, were buried under grassed areas; others were less covered.) No six inch mines were detected. No mines were detected in the grassed areas; scanning was only fair. All detections were made in the first forty feet of the ninety foot lane.

In addition to the problems mentioned in the above discussion of results as of the end of May, certain other problems were encountered at various stages which bear mentioning. In the very first monthly report we mentioned the great difficulty in purchasing suitable dogs within the time frame of the contract. With a longer preparation time, of course, puppies could be ordered and properly raised for the work. Dogs of the proper age were largely unavailable; some located were apparently "dud" dogs and had remained unsold up to this age because of the presence of some defect or other.

There has also apparently been a great demand for Labradors for military and similar research and the supply over the whole country was largely depleted. A number of dog owners and breeders, including those from whom we finally purchased the two Labradors used in this study, were reluctant to sell dogs for research purposes; considerable persuasion was necessary and assurances that the dogs would be humanely treated. Basset Hounds, especially of the working variety, as opposed to show dogs, were simply found to be very scarce. This problem, rather than any inherent weakness or defect of the Basset breed, may have contributed to the poor sampling of dogs we finally obtained.

Another problem briefly alluded to in the passages quoted from the May report concerns extinction effects when the dogs are worked for considerable periods with poor or no success. These extinction effects show in emotionality -- poor response to obedience commands, general apathy in the working situation, etc.

A related problem concerned motivation in general. As mentioned in the Method and Procedures section, food reinforcement was the primary reinforcement used. This was combined with a secondary reinforcement (the bridging signal) and paired frequently with praise, pats, and the like. However, some disapproval, delay of runs, and withholding of reinforcement was naturally necessary for the control of the dogs. Son particularly reacted poorly to such mild punishment and tended to become "negativistic" and deteriorate in his work habits.

As far as primary motivation was concerned, we followed established practices to maintain good health. It might be noted that these were young and still growing dogs. We did not have time to study in detail what would be the minimum amounts of food which could maintain good health. The average daily feeding was about one quart of dry food per dog but was varied within reason and known health requirements according to the dogs' performances.

For a summary discussion of the situation prior to the field tests, we quote again from the May report:

A. Preliminary conclusions based on the limited sampling and time available during this contract and subject to further analysis of data and outcome of tests at Aberdeen:

1. Our limited experience with Basset Hounds indicates they are poor subjects for stringent field training.

2. Labrador Retrievers can detect mines buried in bare earth four months to a depth of two inches. Detection appears to be by olfaction and/or tactile senses and/or visual cues. Detections are possible at deeper depths but reliability deteriorates. Practice appears to improve detection capability.

3. The attention span (or endurance) of Labrador Retrievers limits working sessions to less than one hour.

4. Detection capability seems to vary with soil texture being best in loose sandy soil and poorest in packed, dry soil.

B. Problem areas recommended for future studies:

1. Fundamental studies of motivation and reinforcement of dogs of various breeds with particular emphasis on:

a. Hierarchy of reinforcement classes (i.e., reinforcing value of social contact, food, etc.).

b. Schedules of reinforcement.

c. Breed differences.

2. Also important are physiological, anatomical, and sensory capability variations between individuals and breeds.

Such programs should be laboratory type studies subject to stringent experimental control.

The behavioral program designed and implemented by ABE would have been materially aided by the data from the aforementioned studies.

Field Tests, Conduct and Results: June 21, 1971 to June 29, 1971.

The dogs were prepared for shipment on June 18. They were transported to Aberdeen by van and were accompanied by R. Humphreys, training supervisor, and T. Pultz, training technician. They arrived at Aberdeen on June 20 and on June 21 they were checked into a veterinarian's boarding facility, where they were first dipped, according to his procedures.

Field tests began on June 21 and were conducted twice daily (with the exception of two days, June 25 when one test run was dropped in favor of heavy feeding in preparation for the weekend, when total deprivation was to take place, and June 29 when a van breakdown prevented the second run). On the afternoon of June 22 and the morning of June 23, Marian Breland and Robert Bailey from ABE also observed the tests.

Various personnel from APG were present at the tests: John Romba, an assistant, Dr. Krauss, representatives from the division responsible for laying the minefield, etc. Field test data were taken in some detail by APG personnel who had access to information concerning the number and location of mines in each lane. Photographic coverage was also performed by APG. Because of these arrangements, our own data collection was confined to correct or false run data, but without the information concerning possible missed mines, etc. The other information recorded by our staff was largely qualitative in nature.

From the outset of the trials, certain features became apparent which were different from the conditions under which the dogs were trained at Hot Springs.

1. There were usually present at all the tests considerably more people than the number to which the dogs had been accustomed in their daily runs. This was a minor distraction at the beginning of the tests, but, of course, it is not a serious problem and one which can be readily overcome by a very short training program.

2. It was very apparent that the big guns which were being fired in the near distance were a definite distraction for both the dogs.

3. The soil and its cover were of a different consistency than those on which the dogs had previously been worked. The soil itself was more densely compacted than the level of compaction our oldest minefield had been able to reach in the contract period. The lanes were often overgrown with thick high grass and covered with a dense mat of last year's cut grass. In general, successful detections were accomplished in lanes where the grass had been cut and in lanes where there was little or no grass. We were completely unable to get mine detections in cases where the grass was four to six inches high and where a mat of last year's grass covered the ground. Indeed the mat of grass seemed to cause more problems than the high grass itself.

4. From the dogs' behavior we inferred that there was a difference between the mines sent to ABE for training purposes and those mines which were the targets of the field tests. Very early in the trial series, the dogs would detect the ABE mines which had been laid out on the grass, but would overrun, even after smelling them, the two-year old APG mines.

The tests were conducted in mid-morning and again in mid-afternoon (except as noted above). Each dog received at least one individual run per session; runs varied in length, depending on how the dog was working. If the dog refused to work or became very slow, it was retired from the run. Sessions tended to average 15 to 20 minutes in length. Son executed one very fast, active run which was terminated after 12 minutes while the dog was still working briskly. Each dog had a daily tendency to work one of the two sessions better than the other, but it was difficult to predict which session, morning or afternoon, was going to be better for that dog.

The regular routine consisted of picking up the dogs at the boarding establishment, transporting them in the van to the test site and commencing the runs. Water was available for the dogs at the test site. A regular exercise session followed the completion of the trials for each dog at a given detection session. If ABE personnel stayed at the test site between the morning and afternoon runs, as they did on some occasions to cut grass, rake, etc., the dogs were allowed to roam free for two to three hours between sessions. If ABE personnel did not remain at the site they were boarded until the afternoon sessions.

On June 22, we began "assisting" the dogs, i.e., we attempted to help them make the transfer to the apparently new stimuli coming from the APG mines. To do this, we dug up some of the mines, led the dog to one of these, gave him a chance to sniff, and instructed him to sit. After a few trials of this sort, we began to get detections of the uncovered mines.

With regard to a second major problem, namely, the grass and matted grass, on June 23 ABE personnel used hedge cutters and a rake to cut and rake several of the grassed lanes. The grass was cut as close to the ground as possible and as much of the old matted grass as possible was removed. After this, the dogs did make subsurface detections on low cut grass.

On June 23 (morning) one mine was dug up and the hole left untouched after the excavation. Another "false" hole was dug farther down the lane. Pearl detected the hole from which the mine had been dug but ignored the "false" hole. This detection was a typical detection -- to all appearances just as if the mine were still buried there.

On one occasion a rake was taken to two lanes; the teeth were driven into the ground throughout the lane so as to make depressions all along the lane. The dogs made better and more detections in this lane than in the others that day.

The dogs appeared to work more quickly and eagerly on overcast days than when it was very hot and the sunlight was direct. Temperatures and humidity were generally high throughout the test days.

Motivation proved to be a factor in the dogs' performance during the field tests, particularly in getting the dogs to scan rapidly and thoroughly. By and large, the only food the dogs received during the test days was that which they earned during the trials. The amounts of food per trial varied depending on the dogs' performances. On some occasions larger than usual amounts of reinforcement were given -- the normal reinforcement was one to four cubes of Prime. On occasion several times this amount was given, but there was no noticeable effect of the larger reinforcement during this time period. The feeding schedule on which the dogs operated was as follows:

Date	Amount per Dog
June 17	Fed ad. lib., 5 qts. Purina Dog Chow to each dog
June 18	Nothing
June 19	3/4 to 1 qt. Purina Dog Chow
June 20	1 qt.
June 21	1/2 pack Prime
June 22	1/2 pack Prime
June 23	1 1/2 packs Prime
June 24	1/2 to 1 pack Prime
June 25	5 packs Prime, plus 3 qts. Purina Dog Chow each
June 26	Nothing
June 27	Nothing
June 28	1 pack Prime each
June 29	End of trials - 14 packs Prime each.

During all the sessions, the maximum mine depth detected was 1/2 inch. The first such detection was made on June 23. Following this, the dogs continued to make detections at the 1/2 inch level. However, they did overrun several 1/2 inch mines in lanes where they had made detections. On one occasion (one day, two sessions) in three lanes all mines buried at 1/2 inch or only partially buried were completely detected during the course of the two dogs' trials.

Both dogs were left at Aberdeen Proving Ground.

APPENDIX A

TABLE I
Trial Results by Depth of Mine
(April, May, and June at ABE)

Depth of Mine	No. Correct Trials	Percent Correct	No. False Trials	Percent False	No. Incomplete Trials	Percent Incomp.
SON						
4"	14	16.9	39	47.0	30	36.1
3"	114	46.2	92	37.2	41	16.6
2"	184	60.3	86	28.2	35	11.5
1"	263	64.0	98	23.8	50	12.2
PEARL						
4"	4	57.1	3	42.9	0	-0-
3"	49	71.0	9	13.0	11	16.0
2"	267	80.9	13	3.9	50	15.2
1"	172	72.6	5	2.1	60	25.3

APPENDIX B

ILLUSTRATIONS

FIGURE 1. The dog has been given the command to MOVE OUT and is here scanning with the nose within the lane for a buried mine.

FIGURE 2. The dog has made a probable detection and has begun to probe with the foot.

FIGURE 3. The dog executes the SIT response indicating that a detection has been made.

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